PEARL

The Journal of HEREDITY

STERILE HYBRID MADE FERTILE BY COLCHICINE

(SEE PAGE 291)

Practical Men Have More Children

Ectoplasm and the Genes

VOLUME 30 JULY, 1939 NUMBER 7

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The

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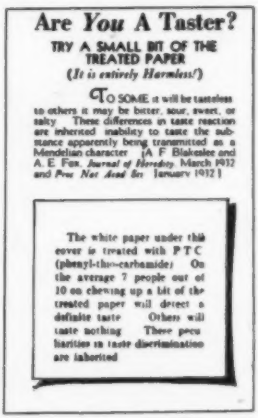
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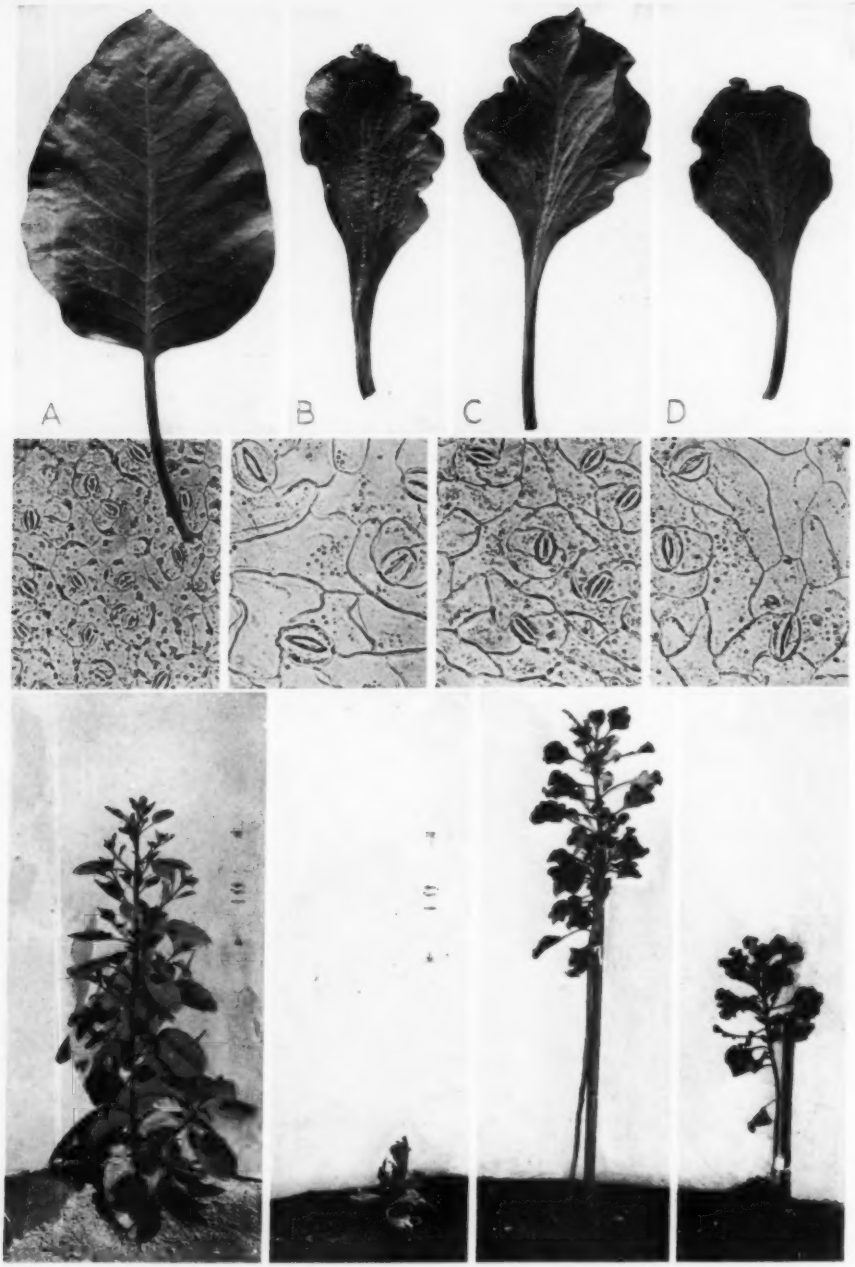


DIPLOID AND INDUCED POLYPLOID FORMS OF NICOTIANA GLAUCA

Frontispiece

Leaves, stomata and plant habits of the diploid (vertical column *A*) and of polyploids Nos. 17, 14 and 15 (columns *B*, *C* and *D* respectively). The polyploids had thicker, differently-shaped leaves, and the stomata were larger and more widely-spaced than in the diploids. Polyploids Nos. 14 and 17 both had 4*n* chromosomes in the pollen-mother cells—two sets from each parent species. The marked differences between these two polyploids apparently were due to the fact that the epidermal tissue, and possibly deeper layers, of No. 17 had a chromosome number higher than 4*n*. The diploid plant pictured here is younger than the polyploids and should be taller for true comparison.

THE INDUCTION OF POLYPLOIDY IN NICOTIANA SPECIES AND SPECIES HYBRIDS

By Treatment with Colchicine

HAROLD H. SMITH

Bureau of Plant Industry, U. S. Department of Agriculture

THE problem of polyploidy in the genus Nicotiana has been of interest for some time, especially in relation to the formation of fertile allotetraploids from species crosses. Chromosome doubling has resulted from hybridization[1,11] and by use of the following artificial treatments: chloroform,[2] x-ray,[3] bacteria,[10] centrifuging,[7] growing shoots from callus tissue formed by growth hormones[6,12] and, most recently, by colchicine.

In a preliminary report, Warmke and Blakeslee[19] stated that 51 per cent of the mature plants grown from colchicine treated seed of *N. Sanderae* had tetraploid characteristics. The growing point of seedlings of the sterile F_1 (*tabacum* × *glutinosa*), were treated by them with a lanolin-colchicine emulsion and 13 per cent produced branches with a higher percentage of good pollen than the untreated hybrids. Some set seed indicating that the sterile hybrid had been transferred into a fertile allotetraploid.

Kostoff[8] has published the following statement concerning his results with colchicine treatments on tobacco: "Applying colchicine solution I obtained tetraploid plants from *Nicotiana rustica, N. tabacum, N. glauca, N. suaveolens, N. megalosiphon, N. velutina, N. alata-Sanderae, N. suaveolens-alata,* . . . and octoploid in *N. alata-Sanderae.*" Some of these were described in a more recent article.[9A].

The data reported in this paper deal with experiments begun in October, 1937, on some Nicotiana species and hybrids for the purpose of investigating the use of colchicine and studying the nature of the polyploids produced.

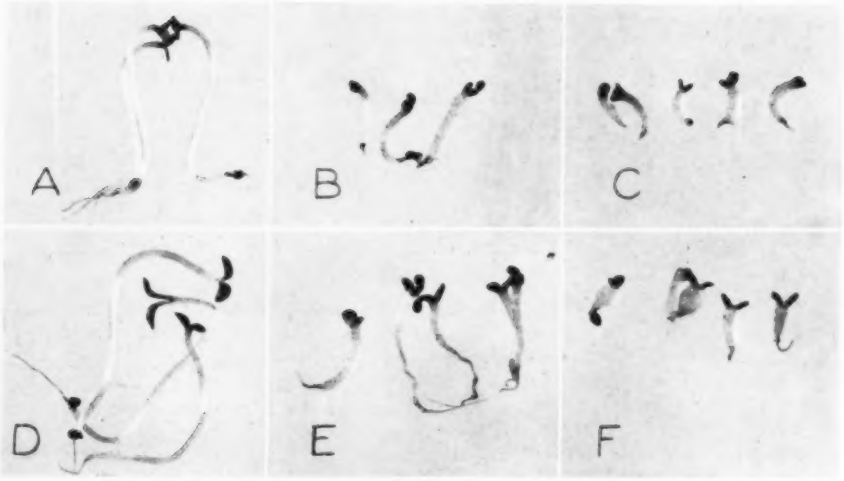
Material, Methods, and Results

1. Seed Treatment

Mature polyploid plants of *Nicotiana glauca, N. tabacum,* F_1 (*tabacum* × *glauca*), and a species hybrid segregant derived from crosses between *N. rustica* and *N. tabacum* have been raised from seed treated with 0.2, 0.4, and 0.8 per cent colchicine for periods of 7, 10, and 14 days. The treatments consisted of keeping a small amount of seed in about two cc. of a water solution of the specified concentrations of colchicine for the three different periods of time.

Controls of dry seed were planted for each treated lot. A second control in which the seed were soaked in water for seven days, corresponding to the seven day colchicine treatment, was made on *N. Langsdorffi,* F_1 (*tabacum* × *sylvestris*) and F_1 (*tabacum* × *glauca*). Soaking, in water only, reduced the germination of *Langsdorffi* and the F_1 (*tabacum* × *sylvestris*) from 80 per cent to 10 per cent. Germination of seed of F_1 (*tabacum* × *glauca*) was not appreciably reduced by the water soaking, a fact which may partly account for the better results obtained with this type.

In a preliminary experiment only the strongest dosage, 0.8 per cent for 14 days, was tried on three different species and eight species hybrids. This treatment affected almost all the plants that came up; but was generally so severe that germination was greatly reduced and the seedlings were unable to develop roots or stem growing points. The swelling and stunting caused by 14-day treatments with 0.2 and 0.8 per cent colchicine are illustrated in Figure 1. Four affected seedlings of *N. glauca*



EFFECT OF SEED TREATMENT WITH COLCHICINE

Figure 1

A—N. tabacum. Control; *B—N. tabacum,* 0.2 per cent colchicine for 14 days; *C—N. tabacum.* 0.8 per cent colchicine for 14 days; *D—F*$_1$ (*tabacum* × *glauca*), Control; *E*—F$_1$ (*tabacum* × *glauca*) 0.2 per cent colchicine for 14 days; *F—F*$_1$ (*tabacum* × *glauca*) 0.8 per cent colchicine for 14 days. Increasing dosage results in progressively increased stunting, and lowered viability.

(C3805-14, 15, 16, 17) and one *rustica* × *tabacum* segregant (C38015) survived the 0.8 per cent treatment and grew to mature polyploids.

Treatments with 0.2, 0.4 and 0.8 per cent colchicine for 7, 10 and 14 days were then made on *N. Langsdorffi, N. rustica, N. tabacum,* F$_1$ (*tabacum* × *glauca*), F$_1$ (*tabacum* × *sylvestris*), and a species hybrid derived from crosses between *N. rustica* and *N. tabacum.* The results were as follows:

N. Langsdorffi. 7 day treatment — poor germination with all concentrations; all seedlings affected in 0.4 and 0.8 per cent, some appeared normal in 0.2 per cent. 10 day treatment — only those in 0.2 per cent germinated and these were all affected. 14 day treatment— no germination. No affected seedlings were raised to maturity.

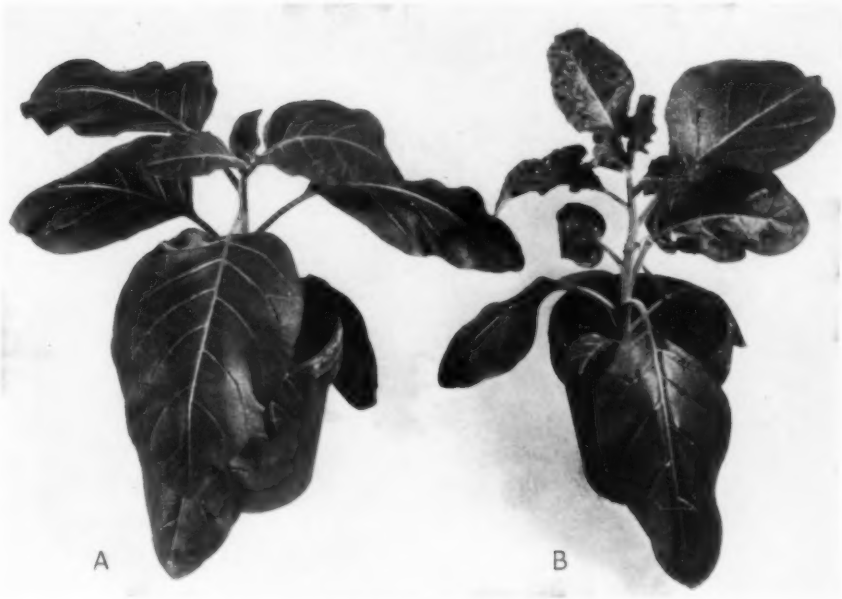
N. rustica. 7, 10 and 14 day treatments — germination poor in all concentrations and for all lengths of treatment. All seedlings were stunted and swollen. No affected seedlings were raised too maturity.

N. tabacum. 7 and 10 day treatment — germination poor in all concentrations, some normal seedlings in 0.2 per cent, but all affected in 0.4 and 0.8 per cent. 14 day treatment — all seedlings affected in each concentration; germination more reduced than in 7 and 10 day treatments. One affected plant from the 0.8 per cent for 10 days' treatment was raised to maturity and had typical tetraploid characteristics.

F$_1$ (*tabacum* × *glauca*). 7 day treatment — no reduction in germination in any concentration; one-half the seedlings in 0.2 per cent were affected, three-fourths of those in 0.4 and 0.8 per cent. 10 day treatment — reduced germination in 0.4 and 0.8 per cent, not in 0.2 per cent; three-fourths of the seedlings were affected in 0.2 per cent, and nine-tenths in 0.4 and 0.8 per cent. 14 day treatment — germination reduced in all concentrations; all seedlings affected in all concentrations. These observations were made on seeds planted directly after treatment. Half the seeds (about 100 in each lot) that were treated for 14 days were dried and kept for nine months before planting. All seedlings were retarded or severely affected; observations made on these plants were as follows:

Concentration	No. retarded	No. severely affected	Total
0.2%	18	55	73
0.4%	4	30	34
0.8%	0	10	10

None of the seedlings has matured yet. Four mature allotetraploids have been raised from treated seed planted directly after treatment. One was obtained from 0.2 per cent for seven days treatment, two from 0.2 per cent for ten days, and one from 0.4 per cent for ten days.



LOCAL APPLICATIONS EFFECTIVE

Figure 2

Effect of meristem treatment with 0.4 per cent colchicine on *N. rustica*. Left: Untreated control. Right: Treated plant one month after first application of colchicine.

F_1 (*tabacum* × *sylvestris*). Germination was so severely reduced that it was not possible to arrive at any conclusions as to the effects of the colchicine.

The *rustica* × *tabacum* species hybrid segregants were affected by colchicine in about the same way as *N. rustica*. No affected seedlings were raised to maturity.

Some general conclusions about treatment of seed with colchicine may be summarized as follows: (1) Species respond differently to the treatment. *N. glauca*, and crosses with *glauca*, stood up best under strong dosages. This may have been due largely to a greater tolerance for soaking in water. *N. rustica* was severely affected by the weakest dosages. *N. tabacum* was intermediate between the two. (2) Affected seedlings can easily be obtained by seed treatment. The main difficulty is to get ones with enough of the meristem affected so that the inflorescence will be polyploid, yet not so severely affected that the stem and root meristem will fail to develop. (3) Seeds that were treated and then kept dry for nine months before planting showed about the same effects as those planted immediately after treatment. (4) All affected seedlings which have been raised to maturity were complete polyploids; i.e., the chromosomes throughout the whole plant and not just a part were doubled. Plants affected by meristem treatment, on the other hand, usually developed only sectors of polyploid tissue in the inflorescence. It appears then, that a higher proportion of growing point cells were doubled by the seed treatments than by the meristem treatments described below. This may have been due to differences in the method or in the condition of the material.

2. Meristem Treatment

The first series of meristem treatments were made on plants of *N. tabacum*, *N. rustica*, and species hybrids derived from crosses between *rustica* and *tabacum*.

DIPLOID AND TETRAPLOID COMPARED

Figure 3

A—Leaf and plant of diploid *N. rustica*. *B*—Leaf and plant of induced tetraploid. The tetraploid plant is definitely dwarfed. It has smaller and thicker leaves with larger stomata. Since the doubled chromosomes are those of a normal species—not a hybrid—this is an autotetraploid.

Four-tenths per cent colchicine was applied in water solution by drops and by spraying.

Six plants of tabacum, varying in size from one and one-half inches tall with two leaves to seven inches tall with nine leaves, were treated twice a day for six, eight and ten days. All plants showed typical distortion of young leaves; but in each case they grew out of the effect so that the inflorescence was all diploid.

Twenty *rustica* plants, varying in size from one and one-half inches tall with four leaves to twelve inches tall with ten leaves, were similarly treated. Typical effects of colchicine so applied to the meristem of *N. rustica* are shown in Figure 2. Three plants did not grow out of the results of the treatment and produced flowers with giant pollen grains. In two, the percentage of giant grains was so small that they were eliminated in competition with normal pollen and no polyploid seed were obtained. In the third (38058-B) a large sector of the inflorescence was tetraploid and in the next generation four autotetraploids were obtained out of 88 plants grown.

No difference in effect was observed between the drop and spray methods; and, since the use of drops was more economical, it was preferred. Plants which grew out of the colchicine treatment were cut back to the effected region, but axillary shoots developing from these areas were never polyploid.

Since *rustica* plants were most easily affected in the four to six leaf stage, which is just before elongation of the stem, three more plants of this age were treated each day with two drops of 0.4 per cent colchicine for ten days. One plant (38076-D) developed a large polyploid sector of the inflorescence, and seed obtained by crossing this plant with the tetraploid 38058-B have produced six seedlings all of which show tetraploid characteristics.

Another *rustica* individual, 38077-1, was treated by smearing the growing point with 0.4 per cent colchicine in lanolin paste. Growth was checked severely, but the inflorescence which developed was partly tetraploid. Seven seedlings out of 35 obtained from selfed seed of this plant had tetraploid characteristics.

Three more *rustica* plants in the six leaf stage were treated with 20 drops of 0.4 per cent colchicine, and after each application the growing point was stroked with a small brush to insure better penetration of the solution through the layer of protective hairs. One plant, C38017A-1, developed an inflorescence that was largely tetraploid and produced seed from which thirteen offspring (family 38328) were grown. Nine of these were autotetraploids. Five seedlings, all tetraploids, have been obtained from self pollinating one $4n$ individual, 38328-11.

Summarizing the results with *N. rustica*, twenty-seven plants were treated and four have been doubled so that part of the inflorescence was tetraploid. Plants with tetraploid characteristics have been obtained from seed of each affected individual. In one series two generations of tetraploids have been grown.

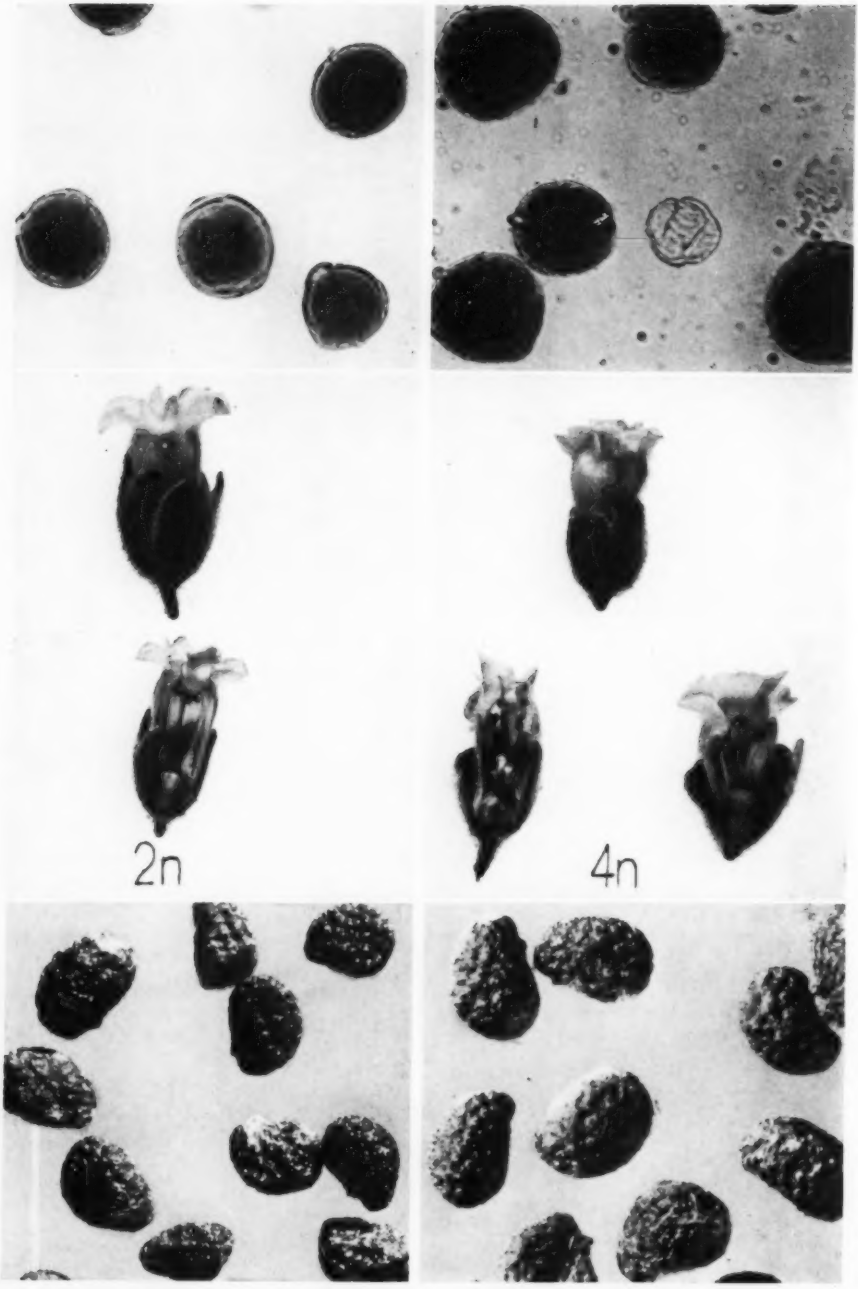
Five species hybrid segregants derived from crosses between *N. rustica* and *N. tabacum* were treated with 10, 14 and 20 drops or sprays of 0.4 per cent colchicine applied to the meristem at the rate of two drops or sprays a day. The plants at time of beginning the treatment varied in size from four and one-half to ten inches in height and had six to eight leaves. One individual (38070-B), from a 14 spray treatment, did not grow out of the colchicine effect and produced polyploid sectors in the inflorescence which were distinguishable by an increased pollen fertility. The fertile pollen produced very few seed, however, and only one seedling has grown. This showed definite polyploid characteristics.

In a second series of experiments on 18 similar *rustica* × *tabacum* segregants, where 20 drops of 0.4 per cent colchicine were used, two (C38010A-X and Y) with fertile polyploid inflorescences were obtained. Thirty-six seedlings grown from selfed seed of C38010A-X all had polyploid characteristics. Three seedlings out of eight obtained from selfed seed of C38010A-Y, the less fertile of the two, were polyploid.

Meristem treatments consisting of 20 drops of 0.4 per cent colchicine were made on 14 plants of *N. glauca* and one, C3805A-1, was affected so that the subsequent vegetative growth had tetraploid characteristics.

The following species hybrids were given a similar colchicine treatment when they were in the four to six leaf stage; but no mature polyploid sectors developed: *tabacum* × *sylvestris* (25 plants), *tabacum* × *tomentosa* (6 plants), *tabacum* × *glauca* (30 plants), and *glutinosa* × *sylvestris* (9 plants). Many of these hybrids were killed by a stem disease prevalent in the greenhouse at the time and, therefore, it cannot be said definitely that the results were entirely negative.

A final series, combining drop treatment with colchicine-lanolin paste, was made on the F_1's of *tabacum* × *sylvestris*, *tabacum* × *tomentosa*, *tabacum* × *glauca*, and *glutinosa* × *glauca*. The method was to apply one drop of 0.4 per cent colchicine every other day to young two-leaved seedlings, and continue this treatment for ten days. The plants were later transferred to thumb pots and, when they had developed about three good-sized leaves, a drop of melted 0.4 per cent colchicine-lanolin mixture was applied to the growing point.



POLLEN, FLOWERS, AND SEED OF DIPLOID (2*n*) AND TETRAPLOID (4*n*)

Figure 4

Normal *N. rustica* compared with induced tetraploid. Pollen and seed of the tetraploid are larger, but the flowers are smaller than the diploid and are usually misshapen.

Out of 25 *tabacum* × *sylvestris* hybrids treated, one plant with a fertile allotetraploid inflorescence, 38103-1, was produced. Out of 25 *glutinosa* × *glauca* hybrids treated, six plants with fertile allotetraploid inflorescences were produced. No polyploid inflorescences were obtained on the treated plants of F_1 (*tabacum* × *tomentosa*) and F_1 (*tabacum* × *glauca*).

Seventeen plants of *N. tabacum* were treated with the lanolin mixture only, and one (38148-1) was affected so that sectors with an increased chromosome number developed in the inflorescence.

The results on meristem treatment with colchicine may be summarized as follows: (1) Polyploid inflorescences or well developed polyploid vegetative parts have been obtained on *N. rustica*, *N. tabacum*, three species hybrid segregants derived from crosses between *rustica* and *tabacum*, *N. glauca*, F_1 (*tabacum* × *sylvestris*, and F_1 (*glutinosa* × *glauca*).

(2) Polyploid seedlings have been obtained from seed of the doubled forms of *N. rustica*, *N. tabacum*, the three species hybrid segregants, and F_1 (*tabacum* × *sylvestris*).

(3) The main difficulty with this method is that treated meristems tend to grow out of the colchicine effect; and, consequently, the main problem is to affect a large enough portion of the growing point so that 4*n* tissue can compete successfully with the more rapidly growing 2*n* meristematic cells.

(4) The number of permanently affected plants in those types where at least one polyploid was obtained are listed at the right.

Description of Polyploids Produced

1. Autotetraploids

N. glauca ($2n = 24$). A total of five polyploids of *glauca* have been produced by colchicine treatment, four from treated seed and one from treated meristem. All had smaller, thicker, and different shaped leaves than the diploid controls; the stomata were larger; the cells of sectioned root tips were larger; and the general growth habit was smaller. The polyploids matured much more slowly than the diploids. They also had less tendency to produce axillary suckers than the normal plants. These differences are illustrated in the Frontispiece.

Although all the polyploids had the above characteristics in common there were definite differences between the plants themselves. A progressive increase in stomate size in comparable leaves of polyploids 14, 15 and 17, as shown by the illustrations in the Frontispiece was accompanied by a progressive decrease in plant size and greater distortion of leaf shape. Plants 14 and 17 both had giant pollen grains (30-40 per cent aborted) and, from counts in the pollen-mother cells, the 4*n* chromosome number. The flowers of number 14 were broader than in the diploids, while those of number 17 were distorted in shape. The differences in leaves, stomata, flowers, and plant habit between these two plants was probably due to the fact that in number 17 the tissue which gave rise to the epidermis was not 4*n*, as in the pollen-mother cells, but a higher polyploid number.*

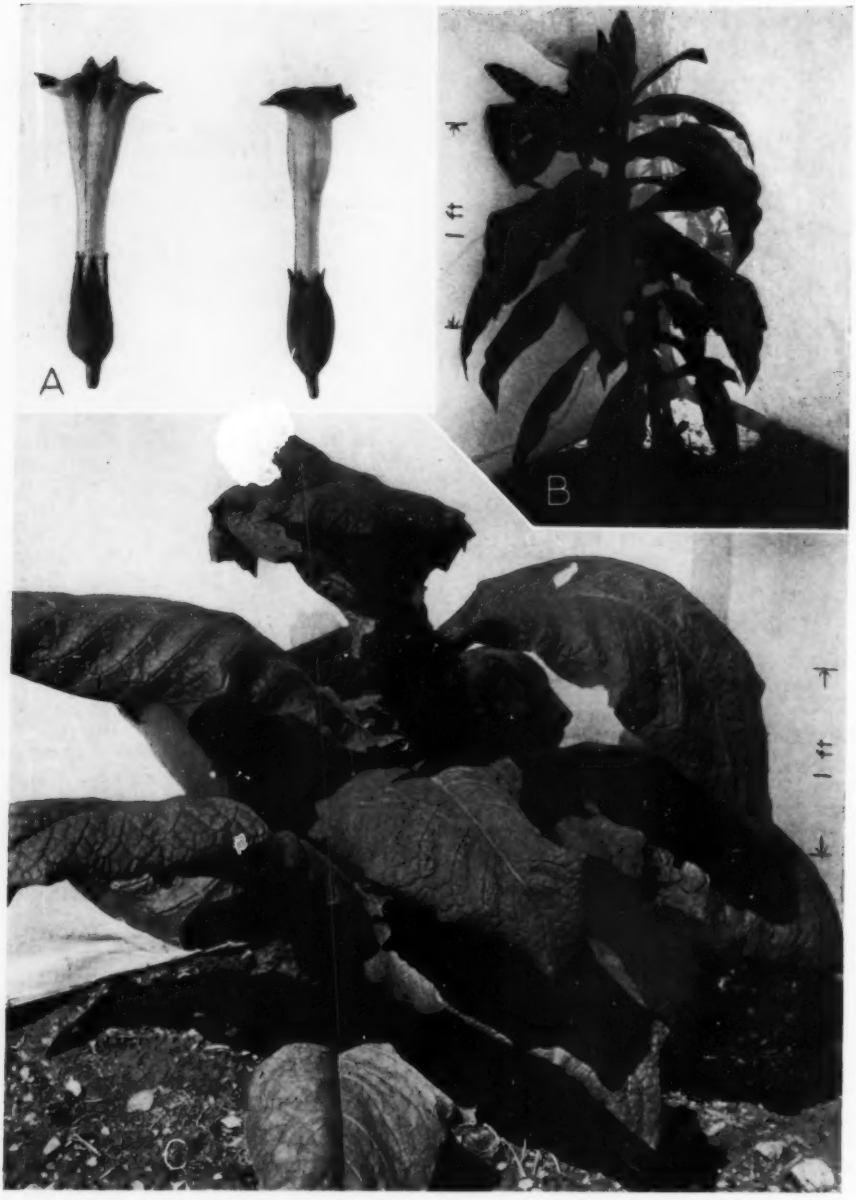
Pratasenja[13] obtained, from regenerated tissue, a tetraploid of *N. glauca* which was described as somewhat retarded in development and having leaves with larger stomata and different venation than diploids. Zhurbin[20] reported a progressive increase in stomata size in di-, tri-, and tetraploids of *glauca*.

TABLE I. List of Polyploids Obtained.

Type	No. Plants Treated	No. Permanently Affected
N. rustica	27	4
N. tabacum	17	1
rustica × *tabacum* segregants	23	3
N. glauca	14	3
F_1 (*tabacum* × *sylvestris*)	25	1
F_1 (*glutinosa* × *glauca*)	25	6
	131	18

12 per cent of those treated grew into plants with mature polyploid parts.

*While this paper was in press Blakeslee, Bergner, Satina, and Sinnott (*Science* 89:402, 1939) have reported the occurrence in *Datura stramonium* of periclinal chimeras in which, as a result of colchicine treatment, the epidermis was 4*n* and the inner tissue 2*n*.



DIPLOID AND TETRAPLOID TOBACCO

Figure 5

A—Flower of the tetraploid of the Madole variety of tobacco (*N. tabacum*) at left; of normal diploid Madole plant at right. The autotetraploid of this variety (*B*) has a smaller plant habit, smaller and thicker leaves with larger stomata, larger flowers and larger pollen grains than the diploid (*C*). The top of the diploid Madole plant (*C*) has been cut out—a cultural practice known as "topping." Normally it would be taller than the tetraploid.

N. rustica ($2n = 48$). Of the four *rustica* plants that had polyploid sectors in the inflorescence as a result of meristem treatment, selfed seed have been obtained from three. Nine tetraploid offspring from one of these—C38017A-1, an individual from an inbred line—had practically identical characteristics. They differed from the diploids in the following ways: larger stomata and pollen, smaller growth habit, thicker and smaller leaves, smaller flowers which were usually distorted, and a decrease in amount and fertility of the pollen. These comparisons between $2n$ and $4n$ plants are illustrated in Figures 3 and 4. Tetraploid flowers in the inflorescence of C38017A-1 had about 25 per cent sterile pollen and about 90 per cent of the fertile grains were giant size. Pollen from two of the tetraploid offspring (38328-8 and 9) was examined and found to be 15 to 20 per cent sterile. Normal diploid *rustica* is one to three per cent sterile. Seeds from the tetraploids were about twice as large as diploid seed (Figure 4). Root tip preparations, from germinated seedlings two generations removed from the treated plant, were examined and an increased chromosome number indicating tetraploidy ($4n=96$) was observed.

Another doubled form of *N. rustica* (38058-B) was of hybrid origin and the four polyploids obtained from selfing this plant differed considerably from each other, although each had the general characteristics of the *rustica* tetraploids described above. The differences may have been due to some variation in chromosome numbers or to the heterozygosity of the parent plant. Diploid sister plants varied among themselves.

Flowers in the polyploid part of the inflorescence of 38058-B had 40 to 75 per cent aborted pollen; and 50 to 90 per cent of the good grains were giant size. Pollen in the polyploid offspring was scarce, clumped, about 50 per cent aborted, and showed some variation but was mostly large size.

There was about 25 per cent pollen sterility in the polyploid part of the inflorescence of the two other affected *rustica* plants, namely, 38076-D and 38077-1. In both of these about 95 per cent of the good grains were giant size.

N. tabacum ($2n=48$). The chromosome number of two *tabacum* plants has been increased by colchicine, one by meristem treatment (38148-1) and the other by seed treatment (9-10). Both polyploids had smaller and thicker leaves than the diploid, the flowers were larger, pollen grains were larger, and fertility was decreased. Comparisons of plant habit and flower size between plant 9-10 and a diploid of the same variety, Madole, are illustrated in Figure 5. About 85 per cent of the pollen were sterile in both polyploids; but a more fertile sector in part of the inflorescence of 38148-1 had only 50 per cent sterility. There was considerable variation in pollen size.

Reduction divisions in the pollen mother cells of 38148-1 were examined and, although an increase in chromosome number was found, there was an indication of aneuploidy rather than tetraploidy. More detailed cytological observations on the polyploid offspring of this plant are in progress.

Six typical polyploids were obtained out of 50 seedlings grown from selfed seed of the fertile sector of 38148-1. Only nine seedlings were obtained from seeds of the more sterile sector, and these were all polyploids. Stomata of the polyploid offspring were spaced wider apart, varied more in size, and were larger on the average than those of the diploids.

2. *Allotetraploids*

N. tabacum × *glauca*. The four allotetraploids produced by seed treatment were large, vigorous plants, as shown in Figure 6, and were about the same size as the F_1's. They had wider leaves, larger stomata and broader, heavier flowers. F_1's were 95 to 99 per cent pollen sterile and formed no seed. The allotetraploids, on the other hand, were about 65 per cent sterile and produced abundant seed.

Occasional fertile pollen grains found in the F_1 anthers were the same size as the allotetraploid grains, and presumably contained a complete set of chromosomes from each species. Comparisons between the inflorescence, flowers and pollen of the F_1 and allotetraploid are illustrated in Figure 7. In addition to gross differences in flower size between the two types there has also been change in relative lengths of style and stamens.

Root tip preparations of germinated seedlings were examined cytologically and an increased number of chromosomes, indicating doubling, was observed. The tetraploid chromosome number is 72.

N. tabacum × *sylvestris*. The one allotetraploid of this cross induced by colchicine meristem treatment had only 25 per cent aborted pollen and produced abundant seed. The F_1, on the other hand, has about 95 per cent pollen abortion and is highly sterile. Offspring of the tetraploid were slower growing than corresponding F_1's and had darker green, coarser-veined leaves with larger and more widely spaced stomata. The greater distance between stomata in this and other double chromosome forms is apparently caused by larger epidermal cells.

An increased number of chromosomes, indicating doubling, was observed in root tip preparations of the allotetraploid seedlings. The doubled chromosome number is 72.

N. glutinosa × *glauca*. The normal F_1 from this cross is a typical dwarf species hybrid with narrow wrinkled leaves, a poor root system, and general lack of vigor. Doubling the chromosomes in the stem meristem, by a combined aqueous solution and lanolin paste colchicine treatment, resulted in the formation of vigorous allotetraploids with larger, wider leaves and broader flowers. Pollen from the tetraploids was 25 to 35 per cent sterile, as compared to about 98 per cent sterility in the F_1. The plant illustrated in Figure 8 developed two distinct sectors, one doubled and the other undoubled, when the meristem resumed growth after being checked by colchicine treatment.

A FERTILE ALLOTETRAPLOID

Figure 6

Tetraploid induced by treatment with colchicine of hybrid (*tabacum* × *glauca*) seed. The plant is about the same size as the sterile F_1 but has broader, thicker leaves with larger stomata.

These allotetraploids were unfortunately killed by a stem disease soon after they had begun to flower so that no seed or chromosome counts were obtained.

3. *Rustica* × *Tabacum* Polyploids

The three families of *rustica* × *tabacum* segregants treated with colchicine in these experiments represent a different type of genetic material than the F_1 species hybrids described above. They have the following genetic history. A large fertile hybrid with 25 per cent pollen sterility segregated from the cross [(*rustica* × *tabacum*) × *rustica*] selfed. This plant, designated as No. 2, had 70-72 chromosomes, obviously largely from *N. rustica,* and at the reduction division formed a varying number of bivalents, most frequently around 30. Plant No. 2 crossed with *N. tabacum,* variety Madole, produced family 38070 which was treated with colchicine. In a sector of one plant, 38070-B, the chromosomes were doubled. The undoubled part of the inflorescence had 95 to 99 per cent pollen sterility, while the doubled sector was only 30 to 50 per cent sterile. A single plant was grown from selfed seed of the fertile sector of 38070-B. It was much smaller than corresponding undoubled forms and had thicker, coarser-veined leaves with larger stomata, Figure 9. This plant was a hyperpolyploid with about 120 chromosomes, as determined by counts at the first metaphase in the PMC. An untreated sister plant of 38070-B was found to have approximately 60 chromosomes.

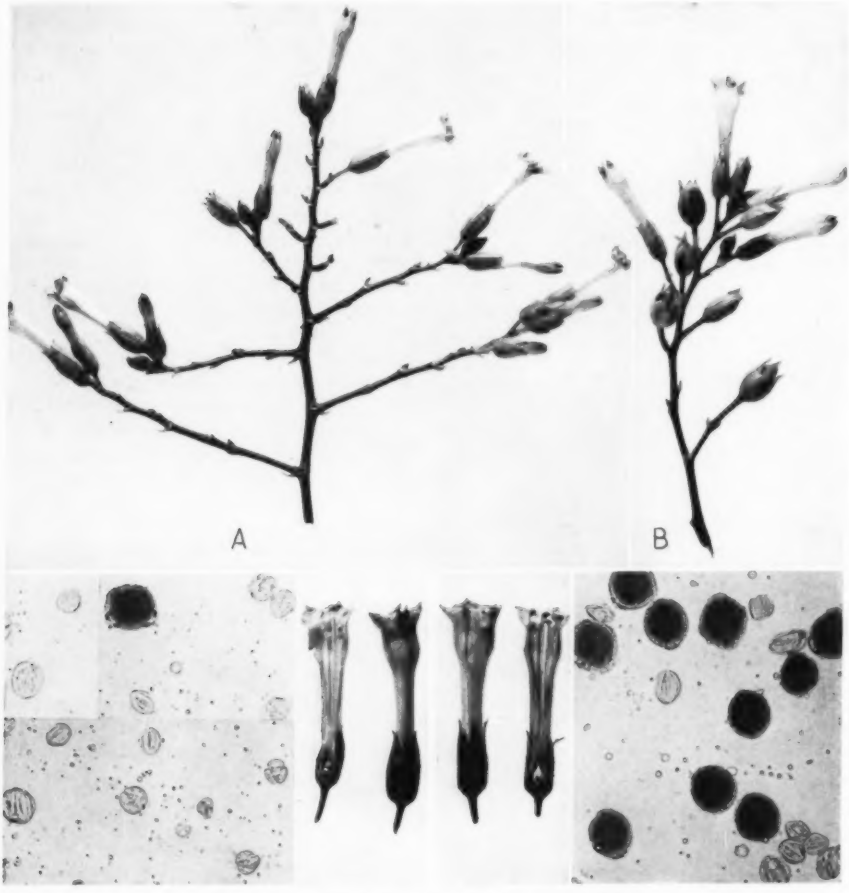
The second family of *rustica* × *tabacum* segregants subjected to colchicine treatment, namely C38015, were derived from crossing an offspring of plant No. 2, decribed above, with *N. tabacum,* variety Maryland Mammoth. Plants from untreated seed of this cross were tall and vigorous with large leaves; but were 95 per cent pollen sterile. One affected individual, raised to maturity from colchicine treated seed, was small, misshapen, and had thick narrow leaves with enlarged stomata; but the entire inflorescence was only 50 per cent sterile and practically all good grains were giant size. A comparison between the doubled and undoubled plants in this family is illustrated in Figure 9.

The third family of *rustica* × *tabacum* segregants treated with colchicine, namely C38010A, were derived from crossing with *N. tabacum,* variety Ambalema, an offspring of plant No. 2 which was different from the parent of family C38015. Untreated plants of C38010A grew to be tall, vigorous plants which were 90 to 99 per cent pollen sterile and set no seed. Two plants, namely C38010A—*X* and *Y,* which were affected by colchicine meristem treatment, were somewhat stunted but fertile and developed numerous seed capsules which contained viable seed. Thirty-six seedlings grown from selfed seed of C38010A-X and at least three from C38010A-Y had thicker, rougher leaves with larger stomata than corresponding undoubled types. Cytological observations on the somatic chromosomes of these seedlings and the PMC of some mature plants showed that the undoubled ones had around 60 chromosomes and the hyperpolyploids around 120.

General Discussion

Two species of which doubled chromosome forms have been obtained, namely *N. rustica* and *N. tabacum,* are considered to be of allotetraploid origin.[4] Each has 48 chromosomes and was probably derived from crosses between progenitors of two 24 chromosome species. One variety of *rustica* and two of *tabacum* used in these experiments were from inbred lines and were large, vigorous strains.

When the chromosome number was doubled, comparatively small weak plants developed which are equivalent to octoploids or double allotetraploids. The general lack of vigor is not due to any effect of the colchicine, itself, since similar characteristics were reported for a tetraploid *N. tabacum* produced by x-rays.[3] The reduced biological efficiency may be due to disturbances of the nuclear—cytoplasm ratio, to less frequent divisions of the doubled chromosome cells, or to other causes. Tetraploids of *N. glauca* were also less vigorous than the diploids even though the $2n$ number is only 24. It is apparent, then, that doubling chromosome complements with-



AN ALLOTETRAPLOID FROM A HYBRID

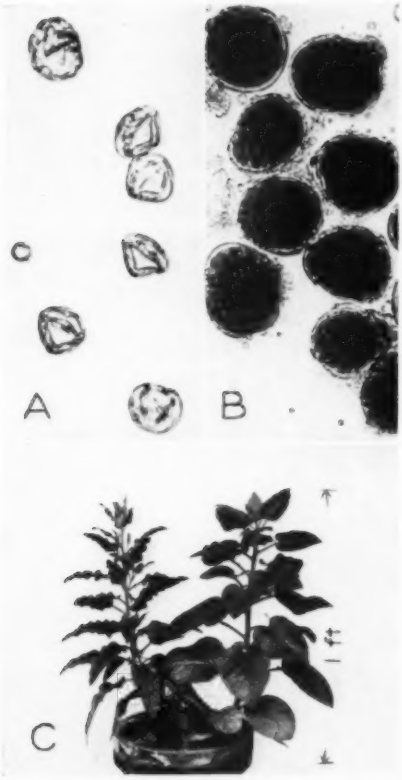
Figure 7

Inflorescences, flowers and pollen of the F_1 (*tabacum* × *glauca*) (*A*) and the allotetraploid (*B*). The tetraploid has broader flowers and an increased pollen fertility. Seed capsules are shown in the inflorescence of the tetraploid. These do not develop in the sterile F_1 and consequently buds continue to form on the elongated branches.

in a species of Nicotiana will, in some cases at least, result in smaller plants. We would expect to find this to hold especially true of species in which the number is already high.

Increased pollen sterility in these recently formed autotetraploids is presumably due to quadrivalent associations of the chromosomes at reduction division and subsequent unequal distribution to the gametes. Similarly, although fertility was increased in the allotetraploids, there was still a comparatively high percentage of pollen abortion which is probably caused by other than bivalent associations of the chromosomes.

Goodspeed[4] has reported a 64 chromosome Australian species which is "a replica of typical *suaveolens* ($2n=32$) on a large scale." Since this apparent



A "SIAMESE TWIN"

Figure 8

A plant of the cross *N. glutinosa* × *glauca* (*C*) which as a result of meristem treatment with colchicine, formed two growing points—on the right tetraploid, and on the left normal F_1. The F_1 is a dwarf hybrid with narrow, wrinkled leaves and 95 to 99 per cent sterile pollen. The allotetraploid is a more vigorous plant with broad, smooth leaves and only 25 to 35 per cent sterile. *A*—shows the sterile grains from the F_1; *B*—the fertile pollen of the allotetraploid.

autotetraploid has survived in nature and is probably highly fertile, and since many cultivated crops of primitive origin, including tobacco, are tetraploids, yet are highly fertile, it seems probable that there is some mechanism whereby quadrivalent and other polyvalent chromosome associations are replaced by bivalents over a series of generations. With these considerations in mind, the recently formed tetraploids are being inbred so that they can be studied from time of origin through a number of generations.

The cross *glutinosa* × *glauca* is of special interest since the F_1 is a dwarf hybrid and the allotetraploid shows pronounced increase in size and vigor. Each species has the $2n$ chromosome number of 24, but they are genetically distant and placed in different groupings within the genus.

No observations on the amount of chromosome pairing occurring in this hybrid have been published. A similar cross, on which such observations have been reported,[5] is *paniculata* (a 24 chromosome species of the "glauca group") × *glutinosa*, where the most frequent number of bivalents was found to be three, and the maximum, five. Bivalent associations are probably as infrequent in the F_1 (*glutinosa* × *glauca*) which indicates that a number of genes from each species may be left without an allelomorph.

If a double dose of any of these genes is necessary for normal plant development, this would account for the dwarfed condition of the hybrid. Weight is added to this suggestion by the fact that the doubled form (allotetraploid) has "normal" size and vigor. This explanation would be tenable for other similarly formed dwarf hybrids and for haploids from inbred lines where the decrease in size and vigor was more than could be accounted for entirely by smaller cell size.

The *rustica* × *tabacum* hybrids represent a different situation than the other species crosses because the female parents were hybrid segregants, genetically nearer to *rustica*, having 70-72 chromosomes; and were 15 to 25 per cent pollen sterile. The male parents were different varieties of *N. tabacum* ($2n$=48). A few hundred segregants from crosses of this sort have been grown during the past three years and all were tall vigorous plants with large leaves, and 85 to 99 per cent pollen sterility. When the chromosome number was doubled, by

STERILE AND FERTILE SEGREGATES FROM A CROSS

Figure 9

Species hybrid segregants derived from crosses between *N. rustica* and *N. tabacum*, family C38015: Untreated plant (*A*) and sister plant (*B*) the chromosomes of which have been doubled by colchicine seed treatment. Inserts show stomata of the two plants.

colchicine treatment, the resultant plants were smaller, but pollen sterility was reduced to 30-50 per cent.

In spite of the high percentage of fertile pollen, it was difficult to obtain seed in some cases (38070-B and C38015). This lack of correlation between pollen fertility and ability to form seed is further demonstrated by comparing the *rustica* autotetraploids (± 25 per cent aborted pollen) with allotetraploids of *tabacum* × *glauca* (± 65 per cent aborted pollen). Very few seed are produced on the former, but large, full capsules developed on the latter. It would be interesting to determine what factors are most important in causing this situation —amount of pollen, pollen germination,

pollen tube growth, ovule development, zygote and embryo formation, or "general plant vigor."

The allotetraploid ($4n$=96) of F_1 (*rustica* × *tabacum*) is smaller than the undoubled F_1 but is a large plant.[9] The hyperpolyploids with around 120 chromosomes, induced by colchicine treatment, were decidedly dwarfed, at least in the first generation. In *rustica* × *tabacum* hybrids, then, unusually high increases in chromosome number are deleterious to plant development. One other case has been reported, for hybrids of this sort, where the chromosome number was above 96. Schwartz[15] obtained, by hybridization, a plant with 114-116 chromosomes which was described as having outstandingly thick leaves.

An attempt was made to grow cuttings of diploids and tetraploids of *N. rustica*, *N. tabacum*, *N. glauca*, and *tabacum* × *glauca*. The autotetraploids did not root as readily as the diploids, but the allotetraploid, *tabacum* × *glauca*, was as successful as the F_1.

Possible Practical Applications

Colchicine, as an agent for producing polyploids, may find practical use in experiments on Nicotiana in the following ways:

(1) No varieties of the cultivated tobacco, *N. tabacum*, have been found which are resistant to the disease downy mildew or blue mold. Most Australian species, on the other hand, are highly resistant to this disease;[17] and it would be desirable to transfer the resistance to tobacco by a series of backcrosses accompanied by selection. Since these species are genetically distant from *N. tabacum*, the hybrid, if viable, would probably be sterile. By doubling the chromosome number in the F_1 with colchicine a fertile allotetraploid should be formed which would furnish a foundation for further breeding work.

(2) *N. glauca* contains the alkaloid anabasine [16] which is dominant to nicotine in the cross *tabacum* × *glauca*.[18] Results of Ternovsky and co-workers also indicate that the allotetraploid has a higher percentage of anabasine than the F_1, or even *glauca*, itself. Since this alkaloid has been shown experimentally[14] to be many times more potent than nicotine in killing black aphids of nasturtium it is obviously of possible practical importance for use as an insecticide.

The allotetraploids with *tabacum*, or possibly other fertile polyploid types, appear to be the most productive source of anabasine since they not only contain a high percent of the alkaloid, but have thick leaves and a vigorous growth habit which should give high yields. Use of colchicine as an agent for doubling chromosomes makes it possible to produce at will allotetraploids from crosses between different varieties of *N. tabacum* and *N. glauca* in order to determine the most desirable combinations.

(3) Strains with high yields of nicotine are being sought as new sources for this important alkaloid. *N. rustica* contains a high per cent of nicotine, but the leaf size and general plant habit is comparatively small. *N. tabacum*, though not so high in nicotine content, has larger leaves and more desirable plant characteristics for cultural purposes than *N. rustica*. By combining the most favorable characteristics from each species, a strain which would exceed either parent in yield of nicotine might conceivably be formed.

The F_1, *rustica* × *tabacum* is practically sterile, while the allotetraploid has a high degree of fertility. Colchicine could be used as an agent for inducing polyploidy to produce fertile tetraploids from crosses between various favorable types of each species.

Summary

Meristem treatments with 0.4 per cent colchicine and seed treatments with 0.2, 0.4 and 0.8 per cent colchicine were made on a number of Nicotiana species and species hybrids. Polyploid forms of the following were obtained:

Type	Treatment	No. Polyploids
N. glauca	seed	4
	meristem	1
N. rustica	meristem	4
N. tabacum	seed	1
	meristem	1

F_1 (*tabacum* × *glauca*)	seed	4
F_1 (*tabacum* × *sylvestris*)	meristem	1
F_1 (*glutinosa* × *glauca*)	meristem	6
(*rustica* × *tabacum*) segregants	seed	1
	meristem	3

The autotetraploids of *rustica*, *tabacum*, and *glauca* were characterized by smaller plant habit, smaller and thicker leaves with larger stomata, larger pollen, and increased pollen sterility compared to the dipoids. The polyploids of *rustica* and *tabacum* had larger seed than the diploids. No seed have yet been obtained from the tetraploids of *N. glauca*.

Allotetraploids of the sterile F_1's (*tabacum* × *glauca*) and (*tabacum* × *sylvestris*) were fertile, had wider and thicker leaves with larger stomata, and were similar in growth habit to the undoubled forms. Allotetraploids of the dwarf hybrid, *glutinosa* × *glauca*, showed a marked increase in plant vigor, leaf size, and pollen fertility over the F_1.

Hyperpolyploids, obtained from doubling chromosomes of some *rustica* × *tabacum* hybrid segregants, differed from sister plants in the following ways: smaller plant habit, smaller and thicker leaves with larger stomata and increased pollen fertility.

The bearing of these results on certain problems of polyploidy is discussed.

Seed and polyploid offspring have been obtained from *N. rustica* (two generations), *N. tabacum*, *rustica* × *tabacum* hybrids, *tabacum* × *glauca*, and *tabacum* × *sylvestris*.

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INEQUALITIES IN THE DIGITS IN SWINE*

JULIUS E. NORDBY†
Idaho Agricultural Experiment Station

THE structural disharmony in the digits in swine discussed below involves unequal development in the length and diameter of the members of the digit pairs. This condition applies to the accessory and chief digits of both fore and hind limbs. While it is recognized that considerable variation normally occurs in the length of the phalanges, metacarpals and metatarsals, and that within certain limits this is not of any great importance in practical hog chiropody, difference in the total length of the digit pairs is a matter of concern to hog breeders because of its effect on weight distribution.

When the inside toe is shorter than the outer, the two do not make a uniform contact with the ground, and a correspondingly larger proportion of the weight is supported by the outer toe (Figure 11). This situation is definitely pathological in its results. The author made brief reference in 1936 to this problem[1] and later described and illustrated it somewhat more fully[2,3] in 1937. In these references the inequalities were recognized as defects from the point of view of practical hog breeders. Invariably when these inequalities occur, the inside toe is shorter than the outer. This applies to the accessory as well as to the chief digits.

In discussing this situation it is essential to get clearly in mind the structure of the porcine foot. There are two principal digits (III and IV in Figure 10), and two accessory digits (II and V in the same figure). In Figure 10 one also observes that the medial rows of accessory digits (II) and of chief digits (III) are shorter than the lateral rows (IV, V). The illustrations also show a larger variation in the length of the accessory than in the chief digits.

Prevalence of the Defect

Almost all hogs have this defect to a greater or less degree. On the basis of observations covering a number of years and involving hundreds of hogs of different breeds in many sections of the United States, the author may safely say that there are relatively few cases in which the members of the digit pairs are equal in size. In detailed studies of thirty feet, that were selected at random from a large available supply at a slaughtering establishment, all showed more or less variation in size in the members of the digit pairs. Hogs that show slight variations are generally accepted as "sound" for all practical purposes.

Significance of Defect

Judges and breeders of swine uniformly reject specimens that show this defect to a marked degree. The defect is very clearly responsible for an unequal distribution of the hog's weight on the foot. When it occurs in the front feet it gives rise to crooked legs, a cramped condition in the chest area, "soreness" and often lameness, and a faulty walk. When it occurs in the rear feet it is a contributing cause for too closely-set hocks, weak pasterns, a splay-footed condition, and an insecure walk. The defect is of less importance to the market hog that is ready for slaughter in six to eight months

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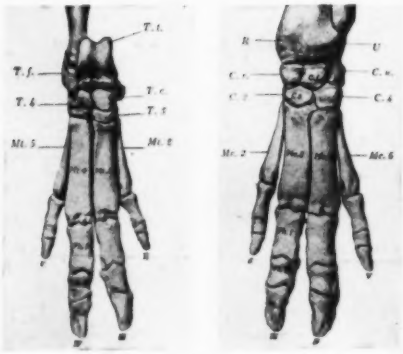


THE PORCINE FOOT

Figure 10

Skeletal parts of front and rear limbs of the pig (from Sisson). The variation in the length of the toes is no doubt what Sisson had observed. This undesirable variation, inherited quantitatively, is controlled to some extent by selection.

UNEQUAL TOES CAUSE LAMENESS

Figure 11

Photograph of forefeet of hog showing unequal development of the inside and outside toes. If excessive, this may cause crooked legs, a cramped chest or too closely set hocks, and a faulty or insecure walk. Courtesy of U. S. Department of Agriculture.

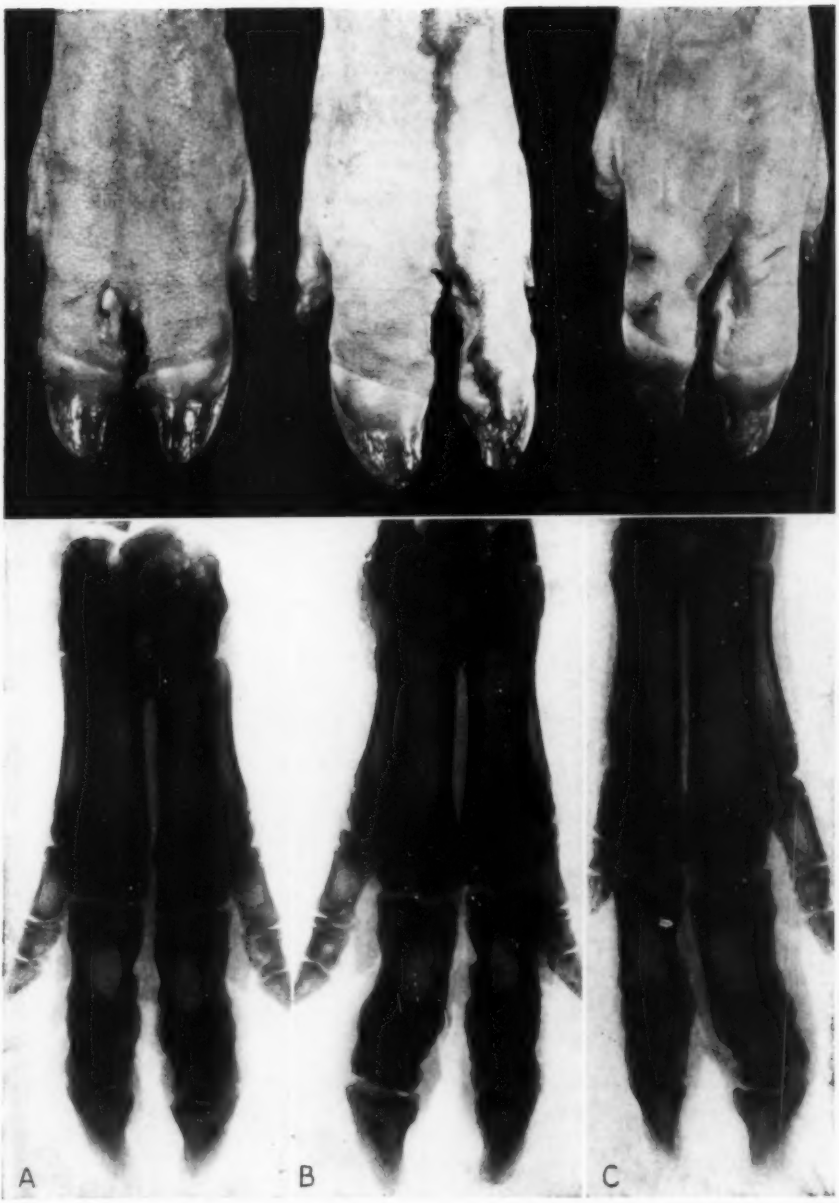
from birth, than to breeding stock that lives to a much more mature age. Even the market hog is adversely affected, however, for he is more efficient in foraging and in the feed lot when he is equipped with good feet and legs. When the "pastern," which involves the 2nd and 3rd phalanges, is long the defect is much more noticeable than if the pastern is short. A long pastern is often too sloping, and consequently weak.

Anatomical Analysis

All three specimens in Figure 12 were selected in a slaughtering plant. The medial and lateral chief digits in Figure 12*A*, which is a left front limb, are fairly uniform in size, and such a foot is generally considered "sound." In the radiograph of this limb (lower photo) there is only a small difference in the size and alignment of the chief digit rows. In Figure 12*B*, which is a right front limb, the development of the lateral row of digits is appreciably in excess of the development of the medial. This inequality in the development of the two rows has distorted the alignment in the lateral row of digits (Figure 12*B*). A similar condition exists in Figures 12*C*, a left pelvic limb. The weight and diameter of the phalanges in the laterals in *B* and *C* were appreciably larger than in the medial digits.

In a number of specimens the total length of the medial row of the chief digits will vary from .1 to .4 cm. shorter than the total length of the lateral digits. The variation in length of the medial and lateral metacarpals and metatarsals usually contributes an additional variation in total length of the digits, and often gives rise to marked differences in the total length of the medial and lateral rows of bones in the limbs below the knees and hocks. Such variations in the length of metacarpals have been reported in the human hand by Gillette[4].

Variations in length, diameter and weight of the members in the accessory digit pairs is often more marked than in the chief digits (Figure 12*A, B, C*). There is, however, a natural harmony in the type of variation in the digit pairs of the accessory and chief digits, as the variation in the members of the accessory and chief digits has never been observed



UNEQUAL TOES DISTORT PHALANGES

Figure 12

Photographs and radiographs of three feet showing the effect of length of toes on the alignment of the phalanges. The phalanges of *A*, a left front foot, of which the toes are nearly equal in length, show little distortion as compared to *B*, a right front foot, and *C*, a left rear foot, in each of which the longer outer toe has twisted the phalangial structure of the foot.

staggered. The medial members are always shorter than the lateral. The accessories do not vary, however, in the same degree as the chief digits. Specimens have been observed in which the length of the accessory digits varied by one centimeter, while the chief digits, in the same limb, varied by .2 centimeters.

Breeders generally pay little attention to variations in the size of the members of the accessory digits. Since swine with extreme variations in the members of the chief digits would be eliminated by breeders, selection has, therefore, had some stabilizing effect on the variations in the chief digits.

While in general the accessory and chief medial members are described as too short, it is not the purpose to infer that they are the total cause of the inequality. Variations in size occur even in the apparently normal members of the chief and accessory digits. Cases may arise, therefore, in which the lateral members vary more or less independently of the medial members, and conditions occur where the variation in the medial members is below normal and the variation in the lateral members is above normal size. Such a condition would probably preclude the presence of genes functioning independently with respect to the development of the members of the digit pairs.

Inheritance of Defect

In a number of matings in which this defect has been rather marked in the boar, although less in evidence in the sows, the pigs have tended generally toward marked defects. In matings in which the boar and sows have been reasonably normal there have been some well defined defects in the progeny. The frequency and magnitude of the variations can be influenced by selection.

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ECTOPLASM AND THE NUCLEUS

More than twenty-five years of research, mostly on marine eggs, have given E. E. Just an enviable reputation as a cell physiologist. From this rich store of experience has recently come a volume* and a broad biological theory imputing to the ectoplasm a determining role in a wide variety of vital activities.

By ectoplasm Just means — p. 75, *". . . . the superficial region of the protoplasmic ground-substance set off from the remainder . . . by differences in physical properties, in structure and in behavior;"*. Regarding its occurrence he states — p. 362, *"In all cells, of unicellular and multicellular animals, the existence of the ectoplasm can be demonstrated."* Although a short list is given of cell types showing a definite ectoplasm his best evidence is taken from the marine egg. From this material the general properties of ectoplasm are developed at length. Its importance for the phenomena of conduction, contraction, respiration and water movements is developed convincingly and in detail. Integration, too, is largely dependent on ectoplasmic activity. In higher animals coordinating systems are of ectodermal origin and their cells are rich in ectoplasm.

I think the most valuable part of the book is the treatment of fertilization. In a variety of egg types the fertilization

*Just, E. E. *The Biology of the Cell Surface*. Pp. xi, 392. Philadelphia: P. Blakiston's Son & Co., Inc., 1939.

process is analysed into its constituent events. Some of the changes are of only a few seconds duration and would escape observation in any but the most careful study. Here, too, the role of the ectoplasm is convincingly demonstrated. JOURNAL readers preoccupied with genetic and nuclear phenomena would do well to read the first eight or nine chapters of this book.

Passing on to the subject of Cleavage and Differentiation, Just proposes a theory of development by *Genetic Restriction*. Briefly it is this — cleavage resulting in differentiation does so by potencies (which are *"chemical reactants,"* p. 327) being taken from the cytoplasm and bound in the chromosomes of the nucleus. For example he states, p. 313, *". . . a fertilized egg, ABCD, . . . forms two blastomeres, AB and CD; there must be differentiation, since the AB and the CD blastomeres when separated give rise to partial larvae."* — p. 314, *"This takes place through the absorption of CD-material by the nucleus of the AB-blastomere-to-be and of the AB-material by the nucleus of the CD-blastomere-to-be. The subtraction of the cytoplasmic materials by the nucleus takes place with each mitotic cycle."*

This theory is proposed by Just in opposition to the theory of embryonic segregation. Apparently it differs from the latter in that material, instead of being segregated into the other blastomere, is segregated into its own nucleus. To me at least, neither theory is as satisfactory or as well substantiated as the explanation of partial development commonly given which I here append in brief.

There are three classes of eggs depending on what happens to blastomeres separated at the two-cell stage. In Class I each blastomere rounds up, the cytoplasm is redistributed, and small normal larvae are produced. Eggs of this type are said to have non-rigid cytoplasm. Examples are found among starfish and hydrozoans. In Class II (partial rigidity type) the separated blastomeres are rigid, they do not change shape but go on dividing as though they were still united, each forms two micromeres and a half blastula. Regulation is slow but the half blastula eventually closes up and becomes a sphere. Gastrulation occurs and small normal larvae are produced. Examples are found among sea-urchins, medusae and amphioxus. In Class III (complete rigidity) the separated blastomeres are never reorganized but continue developing as half individuals. Examples are found among the ctenophores, mollusks, annelids and ascidians. In this explanation we need not assume a differential distribution of materials between the two blastomeres. Contact with each other, the result of first cleavage, alters the structure and physiology of both blastomeres in the same way. They differ only as mirror images. On this scheme there is no need of binding specific cytoplasmic substances within the nucleus. A physical property of the cytoplasm, its degree of "rigidity," determines the fate of blastomeres isolated at the two-cell stage. The existence of an intermediate class, showing partial rigidity, at once supports this explanation and is a difficulty to Just's theory.

The author next proceeds to a criticism of the theory of the gene. Obviously he thinks that the importance of nuclei, chromosomes and genes has been overemphasized. This is a common failing among physiologists who have not had time to follow the rapid progress of genetics or to appreciate its strange methodology. He admits, p. 324, that there is sufficient evidence for the *assumption* (sic) that the chromosomes *have to do with heredity*. However, the gene theory is not the only way of interpreting the vast amount of reliable data accumulated by geneticists. Just suggests a new role for the gene in heredity and differentiation. He states, p. 328, *"The active 'factors' for Mendelian characters do not reside in the genes; rather, the genes by extracting definite materials from the cytoplasm render possible the reaction of the cytoplasm-located hereditary factors."*, and again, p. 329, *"the genes act through their binding of potencies in such wise as to free the action of the cytoplasm-located factors of heredity . . ."*.

It is true that some geneticists, not all, have postulated that genes act by pouring out substances from the chromosomes into the cytoplasm. I am in sympathy with Just's criticism of this concept. Outside of a probable dehydration of chromosomes during mitosis, and a possible giving out of material by the nucleolus, there is no evidence for such action by chromosomes. Nor is there any necessity for this assumption any more than there is need for Just's assumption of chromosomes binding successively different potencies. A theory of genic action now gaining favor contains neither of the above concepts. Briefly put it is as follows. Materials from outside the cell enter the cytoplasm and change it; materials from the cytoplasm enter the nucleus thereby further changing the cytoplasm and changing the nucleoplasm. Within the nucleus the chromosomes take from the nucleoplasm the materials necessary to build up their exact images thus further changing the nucleoplasm. In this way, during periods of differentiation when the cell is also being affected by non-nuclear factors, the genes play their part in differentiation by picking out, in each cell cycle, the same kind and quantity of materials from the changing plasma constituents of the cell. Chromosomes and genes thus affect development and differentiation although the materials they take from the nucleoplasm are always the same.

In the final chapters Just returns to the ectoplasm for further speculation. Mutations induced by experimental means including radiation are indirect effects of directly produced changes in the ectoplasm (p. 352). The genesis of the first life was due (p. 358) to the formation of ectoplasm without which the first living thing could not be separated from its environment. This news will come as a shock to the school of speculators who favor the theories of the pro-gene and of the gene-in-the-free-state, and who regard the virus molecule as living. Chromatin did not come first. It was elaborated from cytoplasm. Evolution, too, is largely a matter of ectoplasm; p. 358, *"The same emphasis that I placed upon the differentiation of ectoplasm out of the ground-substance in the genesis of the primordial living thing, I place upon it as a cause in the evolution of the animal and plant kingdom."*

The second half of the book is stimulating and interesting reading but Just's real contributions, and they are of solid worth for biologists in general, are mainly confined to the first nine chapters of this exceptional book.

C. A. Berger

Woodstock College, Maryland

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Hereditary Deforming Chondrodysplasia

An extensive pedigree of one of the more dramatic hereditary abnormalities in cartilaginous growth is reported by Dr. Charles M. Graney in the *Jour. A. M. A.*, Vol. 112, No. 20, 1939. From this we excerpt the following paragraphs:

Clinically patients with this condition may show visible or palpable bumps over the long bones and deformities, particularly in the bowing and shortening of the forearms. Many of them are below normal height, owing to shortening of the long bones. The symptoms that call for treatment are deformity, pressure on nerves or tendons or interference with the motion of joints. Malignment degeneration is said to occur in 5 per cent of cases, but the percentage is probably lower than that.

* * *

Microscopically these exostoses show an irregular arrangement of cartilage cells and apparently the cells on the metaphysial side of the epiphysial line are responsible for the growths. * * *

Grossly, the appearance of these growths varies from single bony spurs to chondromas with a slim bony shell. They are not found in embryos or fetuses but cases have been recorded in patients at the age of 2 years, and when the lower end of the ulna is the seat of an exostosis the normal ossification of its epiphysis is interfered with, indicating that the process is well established before the age of three. Growth appears to stop when skeletal growths stops at the age of 20 or 22, and regression of the exostoses has been noted in some cases. There is apparently no relation to rickets or syphilis, but the disease is probably related to multiple enchondromas.

* * *

The consensus of statistics shows that males are affected more frequently in the ratio of

(*Continued on page* 320)

THE INHERITANCE OF STRONG PARENTAL INSTINCT

As Proved in the Records of Royalty

FREDERICK ADAMS WOODS

(Continued from June issue)

A Reason for Limiting Families

ALTHOUGH the large families are not due to the desire for male heirs, it still may be that the small ones are. It may be that some of these parents are satisfied with, say, two sons and a daughter, or two sons or even one son. It is only natural that people should differ in the desire for parenthood and for large families. Even among thoroughbred royalty not all are inspired by the parental instinct to an equal degree. In some the wish for a single male heir may well be complicated by desires of perhaps a more selfish nature. When males are in sufficient number such birth-limitation does often take place as an analysis of the sex ratios and sequences in the small families virtually proves. First, a list of the fraternities of four (among the No. 1 Royalties) revealed that a total of 116 births gave 65 males to 51 females. Furthermore if the last of four children tends to be a son it is corroborative evidence — the idea being that the heir now surely has arrived and therefore no more children. Of course, all this is bound up with complicated personal and family problems, matters of which we necessarily know nothing, but the statistical test rises out of it all to demonstrate something which while not true in each instance is true in the average. There are twenty cases where the ultimate is a boy and only nine where a girl is the last child.

Then to bring more conviction, fraternities of three were added. Again the sibs are predominatingly male, sixty-four to forty-seven female, and here again there are twenty cases where the last is a male against seventeen females. Next the families of two bring further proof. Here there are 56 boys to 30 girls and 28 cases where the last is a male to only 15 female.

Families with only one child are strikingly rare in royalty. Not even the fraternities of "children nine and ten" impress one more than this. Actually there are more instances of five offspring than there are of one. Of these few cases of the lone-child, 13 are sons and 8 are daughters. We now have seven tests, all pointing in the same direction, namely that a sufficiency of boys has a marked influence in limiting the large family at least among some parents.

To make it more certain still, three more tallies were made and as these speak the same story it seems sufficient. These are from the second division of the *Almanach*. For one-child cases there are 21 males to 20 females, not in itself a significant difference, but the two-children fraternities show 59 boys to 47 girls. Furthermore the ultimate or second child is a boy 31 times and a girl only 22. The grand total is now given in Table II:

TABLE II. Fertility in Small Royal Families

SOVEREIGN HOUSES

	♂	♀		♂	♀
Families of Four	65	51	Last Child	20	9
Families of Three	64	47	Last Child	20	17
Families of Two	56	30	Last Child	28	15
Families of One	13	8			

MEDIATIZED PRINCES

Families of Two	59	47	Last Child	31	22
Families of One	21	20			
Total ♂s vs. ♀s	278	203		99	63
Last Children	99	63			
	377	266			

It should be observed that not only are the figures 377 to 266 well beyond the laws of chance but what is more convincing each one of the ten small groups indicates a preponderance of males. This identity of the elementary parts — ten times in succession — increases the probability considerably but its exact determination is not of much consequence. No matter how fine the figuring we can not precisely measure this subtle tendency. We can, however, demonstrate that it is there, and it is interesting as bringing evidence for what only common sense must postulate. There is presumably among all civilized peoples some penchant more or less definite towards sons rather than daughters. In Japan it is strong, and also in China where great congratulations at the birth of a boy are said to be matched by condolences for a girl. In India Kipling makes little Kim join in the good wishes laughingly thrown toward some newlyweds, wishing them "a hundred sons and no daughters, as the saying is." Among Europeans and Americans those who have much property to bequeath or a famous name to pass on must think often of this. However that may be, the great point here is that it does not cause royalty to have those notably large families.

What then is the cause? First comes the question of riches. Almost everyone seems to think that the small families of the professional classes in England and America are in a great measure due to small or limited incomes. That this is a genuine cause may well be disputed but that is a long story. On the contrary it is tempting to jump at the conclusion that the large fraternities of royalty are naturally to be expected where everything is made easy and ample wealth abounds. One of the strongest answers to this is that where princes marry nonnobles there are very few children (averaging around 1.5) even when the wives are rich. This evidence was published in this JOURNAL (November 1936). The second reason against the wealth theory is that while nearly all royalty of the "soveriegn" rank and most of those of the princely houses are rich enough to have as many children as they please, the actual appearance of the extraordinary family is confind to several small interrelated groups. In the first division it is nearly all Hapsburg, Bourbon or Leichtenstein. There is no case whatever of a large family (7-12) from a misalliance. In the second division there is only one case in 29 where the mother is not of noble or princely birth. This is less than four per cent, whereas the average for non-noble marriages for the entire list of princes is about 20 per cent. Not only do the very large fraternities, in the second division, come practically entirely from pure bred and aristocratic ancestry, but the mothers are more often than otherwise daughters of precisely the same houses that exhibit the large fraternities in the male lines.

There are twenty-nine cases among the 54 princely families of the mediatized group. *Lobkowicz* shows four, Löwenstein two, Schönbourg two, Thurn-et-Taxis two, and the following one each: Bentheim, *Castell*, Harrach, *Hohenlohe*, Isembourg, Konigsegg, *Neipperg*, Ortembourg, Platen, Rechberg, Salm, Sayn, *Schwarzenberg*, Solms, *Trauttmansdorff*, Waldbott, Waldbourg, and Windisch-Graetz. Those in italics appear also as the family names of the mothers of the seven to twelve offspring.

Of these 29 cases, 16 are strictly within their own caste. Two are with sovereign grade royalty. One of these is with an Archduchess of Austria, a family, as we have already seen, noted for its large fraternities, and ten are with the daughters of old noble houses, i.e. Rohr, Rudenhausen, Beaufort-Spontin, Reichbach, Kinsky (twice), Waldstein, Hollen, Lutzow, and Zesner von Spitzenberg. As before stated one only is with a woman of no title. She was born in Switzerland in 1855. The husband born in 1844 was head of the comparatively unimportant and numerically small house of Waldbott. The members do not bear the usual titles of prince and princess. Their titles are Count and Countess. Taken all together, this single exception which occurred some years ago when large families, outside of royalty, were

more frequent, truly seems but the exception that proves the rule. Wealth or lack of wealth can scarcely account for these observed differences. Wealth may favor the birth and rearing of moderately large families—say from three to six—but can not account for the very large ones or for all the facts here found.

That the Catholic religion has no bearing in the matter has already been indicated. Apropos of this another point may be made, namely, that while the sovereign houses (first part of the *Almanach*) are half Protestant, the mediatized houses (second part) are more often Catholic than Protestant (31 to 9) with the remainder, within the same family, partly Catholic and partly Protestant. Yet royalty of the first part has more offspring on the average than that of the second, being for each marriage 3.62 to about 3. Also, for its numerical total more very large fraternities are found for royalty of the first rank. For the mediatized, with a total population of 1,677, we find 29 cases of families of more than six. These total 221. The first grade royalty with a population of 895 has 17 cases totaling 129. The second grade as already stated shows one case to 57.8 persons, the first grade a little more in proportion, being one case for every 52.6 persons. When we consider the third part of the *Almanach* the same evidence shows forth. The various princes, dukes and counts have fewer very large fraternities than their social superiors (one to 86.5 persons) yet they are even more Catholic than the second grade. Out of 223 of their houses only 41 are Protestant. Eleven are Greek Orthodox and 166 are Catholic. Thus 22 per cent of the houses are Protestant, but out of the 37 cases of large fraternities, 13 are Protestant, making 28.5 per cent. Thus here again the Protestants beat the Catholics.

Parental Instinct Varies

If it is not the form of religion, and it is not wealth, and it is not desire for heirs-male, then what is it? The best answer seems to be heredity. The whole series of data from the extremes of fecundity to the quasi-sterility of those who make misalliances is satisfactorily explained by the ordinary principles of human inheritance governing complex traits. The parental instinct like other important human attributes differs in different people in graded amounts. It is not "there or not there." It is not a question of yes or no. Men can not be divided into those who have health and those who have it not, into those who are intelligent and those who are stupid, into long lived or not long lived, into good and bad, or tall or short. For such complex and blending differences there are no visible unit characters. The laws of Mendel may be there but for all practical purposes they are masked under the multiplicity of the determiners. These highly involved and usually extremely important human differences do, however, as has been abundantly proved, obey the laws of regression and show diminishing ratios of correlation in proper proportion to remoteness of consanguinity. Although here is blended inheritance, so called, the determiners for these characters do not by any means entirely blend. In the reduction division of the chromosomes when half of the entire number are cast out whole just before the creation of the new being, there is for each sib in each fraternity a somewhat different array of genes and chromosomes, the only exception being for one-egg or "identical" twins. Thus the parental instinct should in a similar way to stature, longevity, intelligence, moral superiority, etc., tend to run in families though not show itself in each member to anything like the same extent in any set of brothers and sisters or other group of close relations. It is just this fact of contrasts (alternative inheritance) among close relatives, combined of course with their statistical average resemblances that makes us believe so strongly in the inheritance of mental, moral, and physical traits. Environment can not well account for such differences. Heredity can.

The same sort of distribution of the facts is found for fecundity. As we go outward on a great imaginary chart from a center where may be placed the most

ancient and historically important of houses like Hapsburg and Bourbon the fertility falls off in unbroken stages. The high marks are for certain families, Bourbon, Hapsburg, Lobkowicz, Leichtenstein, etc., but not for every member. Some remain batchelors or marry late in life and then often make misalliances with women too old to have many children. Sometimes a prince becomes a priest or princess a nun. No other general explanations can so well cover all this ground as can heredity alone.

To the question why these people have so many offspring the best answer is a very simple one, they like children; they have them because they want them. And it is partly just this innate desire for germ-plasm immortality that has helped to place these peculiarly situated people where they are today. Their ancestors on all sides for hundreds of years have generally had very much the same feelings. Only in part have they lived for themselves. They have also lived for their children and their children's children. Their ambitions have been for dominance, for the formation of dynasties or for their maintenance, for conquest and for power and wealth, and this especially in the form of landed estate. Their types are essentially practical, and their abilities when noteworthy have been almost solely in one or the other, or both, of two branches of activity, namely warfare or government (including diplomacy). It is just this practical type (prominent business men for instance) ambitious in a worldly way that even today is likely to have plenty of children. Statistics for this statement will be given later. First it is necessary to demonstrate that royalty can properly be considered to belong to such a group.

In *The Influence of Monarchs* (pp. 258-263), eight reasons are given for concluding that the differences among the sovereigns of Europe from about the fourteenth century to the close of the nineteenth which have frequently manifested themselves in conspicuous ability are due more to heredity than environment. At the same time I discuss the nature of their abilities and I state (page 262): "Monarchs and princes have shown their genius chiefly in war and government. They have become distinguished more as men of action than as men of thought." Their literary contributions are then enumerated and the names of eight sovereigns and princes who have very creditable positions in the history of literature are given. These are Alfonso X of Castile, King Deniz of of Portugal, James I of Aragon, James I of Scotland, Charles of Orleans, Thibault of Champagen, Sancho IV of Castile, and Juan Manuel, nephew of Alfonso X.

"In the domain of science (with exception of military science) their activities have been slight, never approaching genius and rarely exceeding the merit entitling them to be classified as patrons. Prince Henry the Navigator of Portugal is in a way an exception. He was doubtless the personal initiator of the great maritime discoveries of the fifteenth century. Everything points to his being truly a great character, a soul filled with grand ideas but from the fragmentary information we possess he seems more of a colonizer and crusader than man of science in the strict sense of the word."

Contrast this with their records as soldiers and governors. In *Mental and Moral Heredity in Royalty*, I pointed out in 1906 that of a total population of 823 there are about 20 of the intellectual capacities of Peter the Great, Gustavus Adolphus, William the Silent, Isabella of Castile and Catherine II of Russia. All are practical types. In *The Influence of Monarchs* the following outstanding and distinctly able rulers are listed. Their chief characteristics are briefly summarized in the appendix: For France, Philip Augustus, Blanche the regent, Louis IX, Catherine de Medici, Henry IV, Louis XIV. For Castile, Alfonso the Noble, Alfonso XI, Isabella the Catholic. For Aragon, James I the Conqueror, Peter III the Great, Ferdinand I the Just, John II, Ferdinand the Catholic. For united Spain, The Emperor Charles V. For Portugal, Alfonso I, Alfonso III, Diniz, Alfonso IV the Brave, Peter the Severe, John I the Great, John II. For the Netherlands, Philip I the Good, Charles the Bold, William the Silent, Maurice of Nassau, Frederick Henry, William III.

As space will not admit and as the enumeration of names is tiresome, especially if not well known to the general reader, let us close this exhibit (which is given merely to prove that eminent royalties have been intensely practical) by setting out in a few words the salient traits of some of the better known regal personalities. These tabloid portraits are copied word for word from the parallel columns in *The Influence of Monarchs* where their influences on the political and economic conditions of their countries are measured. (At that time I had no theory as to the increased fecundity of practical people. This makes the study more objective.)

HENRY VIII of England: Extraordinary vigour of mind and inflexibility of will. Accomplished and versatile, but imperious, selfish, cruel and sensual. ELIZABETH: Extremely able, scheming, practical and brave. Vain, luxurious, willful, mendacious, and vindictive. Patriotic and unusually popular.

PETER THE GREAT of Russia: Extraordinary ability, will-power, and energy. Impulsive, passionate, tyrannical, but often clement. Coarse, brutal, licentious, an epileptic. CATHERINE THE GREAT of Russia: An extraordinary character. Ambitious and courageous. Had great enthusiasm, resolution, natural wit and insight. Charming in manner, with boundless good humour, but was heartless, unscrupulous, and extremely licentious.

MARIA THERESA of Austria: Brave, able, very industrious, economical. Kind, charitable. A good wife and mother. Strict, even illiberal in her prejudices.

GUSTAVUS ADOLPHUS of Sweden: Of exceptional genius. A great warrior and statesman. Adored by his subjects for his many noble virtues.

FREDERICK THE GREAT of Prussia: Broad and comprehensive genius. Great firmness of will. Insatiable ambition and love of power. An indefatigable worker. Cold, cynical and arbitrary, but not devoid of personal attachments. Attentive to justice and the welfare of humanity. For Frederick let us quote the opposite column where the condition of the country is given in condensed form: Great progress in nearly every department. Seventy million thalers in the treasury at the close of the reign. Army raised to 200,000 well-disciplined troops. Agriculture improved. Colonies of immigrants established. All kinds of manufactures flourished, especially silk. Prussia became for the first time recognized as a power in Europe. At least 100,000 foreigners came into Prussia and altogether the population increased enormously. "It is not pretended, however, that Frederick's rule made his subjects happy" (Tuttle).

Since this research *The Influence of Monarchs* is to a great degree objective and impartial and the general results prove the great and direct influences of personal leadership, one could get an impressive idea of the practical qualities of the able rulers by reading the accounts of their achievements. But as this would make too long a story a good idea can be gained by quoting part of what I wrote concerning the reign of Maria Theresa of Austria:

When Maria Theresa came upon the throne in 1740 the finances were exhausted, the national credit was gone, agriculture was in a bad state, of general helplessness pervaded everything. It seemed as if Austria was to be devoured by her enemies,—Saxony, Bavaria, Prussia, Spain, and Sardinia. Before Maria Theresa's death, forty years later, everything was changed. Financial strength was reestablished by a rigid economy, coupled with improved taxation, the various portions of the nation were unified, commerce and agriculture improved, the army was reorganized, the navy began to be a force,—in fact, Austria had become a decisive power in the affairs of Europe. [Her practical wisdom is shown especially in the ways that industrial improvement was brought about. Restrictions concerning trade were removed.] Technical schools were established and skilled foreign artists were encouraged to immigrate.

Practical Men Have Many Children

In *The Relation Between Intelligence and Birthrate* in the Proceedings of the International Congress for Studies Regarding Population Problems which was held in Rome in 1931, I gave figures showing that practical types of successful men have two or three times as many children as the literary and artistic. Since then I have found more evidence in the same direction. The most striking of all is the surprisingly high fertility of British business men who are sufficiently prominent and successful to be included in the English *Who's Who*. In numbers of living offspring they just about rival royalty of the upper grade. This research which I hope soon to publish is not completed but enough is at hand for a summary. From letters *A* to *R* the grand average for 354 business men is 3.31 adult (and living) offspring, ranging around 30 years old. The certainty of the high fecundity is shown in the uni-

formity of the alphabetical subdivisions. Not one falls as low as three. A-B, 3.3; C, 3.6; D, 3.3; E-G, 3.6; H-J, 3.3; K-L, 3.4; M-R, 3.1. There are 38 cases where no data are given as to whether there are any children or not. These have been counted as if they were childless. In most of these it is probably so. This is the conclusion one draws since other matters, like birth, education and marriage, are duly recorded. There are a few instances where the biographies are extremely brief on all matters. These have been left out of the reckoning. If all those giving no data about children are disregarded the average would be raised to three and seven-tenths. This is counting it too high, but it should be a little more than 3.31 which is one of the highest net fertility averages that I have yet come across. In the same article for the International Congress at Rome, already referred to, I show that probably from 15 to 25 per cent should be added for those who really have offspring but fail to record them. If it is taken at 15 this would raise the grand average for the business man to 3.37; if 25 per cent, then it becomes 3.40.

At 3.37 it is significantly higher than any in the *Almanach de Gotha* except that for the *crême de la crême* (reigning sovereign houses) where the average registers 3.32 including bachelors. It is about twice as high as the general run of *Who's Who*, which is only about 1.6, and three times that for artists and authors. The average for meditized royalty is only about 2.5 if bachelors are counted, and for French nobility about 2.0, for Italian nobility about 2.14. This great fecundity for contemporary British business men is surprising and undeniable, and very significant for eugenical studies and also for explaining why the higher royalties have so many children.

This idea that royalties are fecund because their ancestors were gifted in the arts of war and government gains weight when we regard the fertilities of two different types of men of genius. Therefore let us now view a list of the most famous men of all time. My list is founded on that compiled from encyclopedic space by J. McKeen Cattell and published in the *Popular Science Monthly* for February, 1903. His is a useful list entitled "A Statistical Study of Eminent Men." This "space method" of his, as it drags in and places in the high ranks such men as Louis XVI and Napoleon's incompetent or mediocre marshals, needs obvious corrections. I have been working from time to time for a number of years on the improvement of this list by various methods including the use of the "adjective method of praise or blame" described in "Historiometry as an Exact Science" (*Science*, April 14, 1911). For this reason I have dropped overboard a good deal of dead wood; yet the following are certainly worthy of the word "eminent." They are selected as "practical" in contrast to geniuses in the domains of literature and art, and the names and the numbers of their mature offspring are here given: William Pitt, Sr., Earl of Chatham 5; The Duke of Wellington 2; Cromwell 6; Peel 7; Lincoln 1; Thomas Jefferson 2; Canning 3; Bright 6; Russell 6; Alexander Hamilton 7; Robert Lee 7; and William Penn 8. To these must be added, as not the parents of mature offspring, the names of Napoleon, Washington, Palmerston, Mazarin, Richelieu, and Disraeli. These eighteen most eminent statesmen and soldiers of modern times had sixty offspring who lived at least beyond twenty-five years of age. The average is three and three-tenths, almost the same as for notable modern British business men and the royalties who are living today.

In strong contrast to this is the record drawn from the biographies of the greatest artists, authors and scientists. It is only with the utmost labor that one can collect these facts, for encyclopaedias and sometimes biographies are strangely silent on this eugenic question, but as far as yet continued I have found that from the time of Dante, for the most eminent artists, authors, philosophers and scientists, the average is very low indeed. Beginning at the top of the list the following were childless or without legitimate offspring: Voltaire, Bacon, Goethe, Luther, Raphael, Descartes, Michel-

angelo, Kant, Lock, Calvin, Rousseau, Johnson, Petrach, Erasmus, Hume, Gibbon, Pascal, Bossuet, Hobbes, Swift, Tasso, Pope, Swedenborg, Leonardo da Vinci, Camoens, Fenelon, Carlyle, Rabelais, J. S. Mill, Goldsmith, Wycliffe, Harvey, Canova and Cervantes. The research is not sufficiently finished to report a total of sufficient magnitude, but it is evident that the average will not be more than about one adult child apiece, very much like moderns when their life interests are for literature or art.

What is the reason for this strong contrast between the fecundity of the two types? I will suggest the following explanation as covering a good deal of the ground. First, it will be admitted by anyone dealing with the classification of large groups of men of genius (ignoring a few exceptions) all can be placed at once in one or the other of the two categories "practical,"—being statesmen, soldiers, etc., or scientific,—literary,—artistic. The wordings "men of thought" or "men of action," often used, are objectionable as this seems to imply that such men as Cromwell, Lincoln, Jefferson, Alexander Hamilton, Napoleon and the Duke of Wellington were not men of thought.

Second, it is my opinion that the whole matter is bound up with the creative instinct. It is part of the longing for immortality,—the natural human wish to be remembered after one is gone. To a great extent the artist hopes to live in his painting, the poet in his verses, the scientist in his discoveries. On the contrary the business man must have children and grandchildren to keep his memory green. The same applies to noble and royal people and to political and military leaders. They also hope to live in their work, but not so much so as the other type. They do not work so much "for the joy of the working." Hence the greater number of offspring.

Before closing it is well to add two more points. When one thinks of the great rejoicing recently in Italy on account of the birth of the first boy to the Crown Prince and the consequent three-holiday celebration one might exclaim: Surely it is more important for reigning sovereigns to bring up large families than for ordinary people. The answer to this is that those royalties who have the largest families, Bourbon-Parma, Bourbon-Two Sicilies, Bragaza (Capet), Hapsburg-Tuscany, and a younger branch of Leichtenstein, are not, and have not been for several generations reigning over anything. There is no correlation between size of family and practical needs of the state. Indeed I believe it to be slightly negative.

Another interesting fact which shows how deep down in their natures is the desire for children is that they have today as many offspring as they did hundreds of years ago. In *Heredity in Royalty* which deals with sixteenth to nineteenth century individuals the relationship is shown between the grades for virtues and number of adult offspring. There are ten grades. The four central grades average 3.1. The mean for contemporaries is slightly higher, being 3.3 and is exceeded only by the two highest grades for virtues, i.e. 9 and 10. In these grades for virtues are included honesty, kindliness, unselfishness, reliability, etc. —all the general moral qualities, and also the domestic virtues, faithfulness, sex morality, etc. These upper grades average about 3.9. It is these people who have passed on the strong parental instinct and improved the general moral level which in some ways is better today than it was in the past.

It may occur to the reader that the statistics here given are not confined to adult offspring as was the case in *Heredity in Royalty* where only those who reached the age of 25 were considered. But the offspring are not often young children, and for several reasons it is not probable that many will die. Only about five per cent are under five years, and only living children are included. To offset this there are a good many older persons,—brothers and sisters of those living, who because they are now dead are not listed in the *Almanach*.

Similars Marry Similars

There is another factor which should

be in the forefront in discussing all problems of human evolution, historical and social changes and the general course of civilization, and that is the tendency for people to marry those similar to themselves. This is technically known as assortative mating. It has been abundantly proved, for instance, that tall men do not tend to marry short women, nor are geniuses attracted by morons. The evidence for assortative mating is to be found in Popenoe and Johnson's *Applied Eugenics,* and also in Dr. A. E. Wiggam's *The Next Age of Man.* Assortative mating holds for not only stature, eye and hair color, but also even for insanity and longevity. For general intelligence it is particularly high, the coefficient running to .60 or .70. Similarities in disposition, temperament, and tastes also act as affinities. Surely the wish to have many children must more often than otherwise, bring about (for a strong parental instinct) a positive assortative mating. However this may be, it is very unlikely that in these upper social classes large families would occur unless both parents desired them. Among distinguished British business men and among royalties and the nobility it seems as if the men, as young men, have wanted many children and have picked out young women with the same tastes.

Some investigators following the lead of Galton lay a good deal of stress on inherited partial sterility to account for small families. That this enters into the problem somewhat appears more than likely, though it can not account for the rapid decline in the general birth rate witnessed in the last few generations nor for the facts found here. Investigators have found the correlation ratio to be only about .10.

Conclusions

Taking it all in all the conclusion to be drawn from the data presented here — and in my former articles—is that fecundity is inherited and in the upper classes, at least, correlated with mental and moral superiority, but that it is not so much physical as psychical and bound up closely with the parental instinct.

In closing this article it is worthwhile to note again the striking fecundity of the wives of business men, of the higher nobility, and especially of royalty of the sovereign grade. Even allowing for the bachelors the males average to leave well over three adult offspring. If there are now 900 of both sexes and they left only three survivors for each one of the masculine sex, there would be 1,350 in the next generation and 2,025 in the next. Then, counting three generations to a century, there would be in 200 years 10,-251; in 400 years 116,711; in 600 years 1,334,135, and in 900 years a great many millions. Of course no accurate predictions can be made, but the fact that they have been flourishing now for about 900 years and that the non-reigning houses are having just as many children as the reigning makes it not at all too much to predict that the chances are that many of these families will be still going strong hundreds of years from now and that they will be more numerous than they are at present.

Hereditary Deforming Chondrodysplasia

(*Continued from page* 312)

about 3 to 1. In this series there are eight males and seven females.

* * *

SUMMARY

1. Fifteen cases of hereditary deforming chondro-dysplasia in three generations were observed. Nine of these were proved by x-ray and clinical examination by the author; the others are accepted on the strength of clinical examinations by other physicians in two cases and on the family history in the other three.

2. The ten cases reported illustrate the heredity factor. There are three brothers affected; two of them have two affected children each.

3. There are two cases of shortening and bowing of the forearm.

4. The multiplicity of exostoses is shown in all the cases. Only enough roentgenograms were taken in several of the cases to prove the diagnosis and not to show the distribution or number of exostoses.

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